REVIEW: THE COMPARISON OF GEOMETRIC DESIGN USING CIVIL 3D SOFTWARE AND MANUAL METHOD

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Abstract

Roads provide significant social advantages while making a significant contribution to sustainability and economic progress. For development and progress, roads are crucial. roads that will expand access to more areas and improve socioeconomic development. Alignment refers to the placement of the design for the highway's centerline on the ground. The main criteria for alignment are that it must be quick, simple, secure, and affordable. The three primary elements of geometric design are cross-section, horizontal alignment, and vertical alignment. This review paper uses AutoCAD Civil 3D and a manual method to show how a roadway is often designed. It is modelling software that makes it easier and more convenient to complete modelling tasks. Civil 3D modelling makes alignment construction swift and simple to comprehend.

Keywords- Civil 3D Software, Geometric Design, Road, Manual Method, IRC, Design Speed, Superelevation.

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1. INTRODUCTION

The selection, sizing, and positioning of highway geometry components are supposed to take into account factors including sightlines, car stability, driver comfort, drainage, cost effectiveness, and aesthetics. There is some drafting involved in the design process, as well as numerous computations and analysis. The design engineer is typically responsible for Using stations, elevations, and coordinates, map the road profile and determine the orientation of the route (or bearings), computing sight distances, vertical curve lengths, horizontal curve radii, computing how much earthwork is done and performing a variety of more computations and analysis to determine the best alignment while meeting design requirements and constraints. the location and vehicle count, bicycle, and sidewalk lanes, as well as their cross slopes, shoulders, and drainage ditches, etc., are displayed on the highway cross section. The project's goal was to show how quickly, easily, and precisely roadway geometric design may be accomplished. The process for designing roads with AutoCAD Civil 3D has been described. The identical route was also manually designed, and the outcomes were favourably compared to those of AutoCAD Civil 3D.

A. Geometric features

The fundamental goals of geometrical patterns include maximise effectiveness and security while limiting expenditures and harm to the environment. Geometric design also has an impact on community objectives, such as facilitating obtaining employment, schools, businesses, and residences, accommodating a variety of modes of transportation, such as cycling and walking, taking public transportation, and driving, and reducing fuel consumption, the environment, and emissions harm. The dimensions and arrangement of the highway's visible components are governed by its geometric design. The emphasis of the geometric design aims to meet the requirements of the car and the driver, including those of efficiency, comfort, and safety. The cross sectional elements, sight distance consideration, horizontal curvature, gradients, and intersections are the characteristics that are frequently considered. The psychology and the mannerisms of the driver, the characteristics of the car, and the traffic patterns, such as speed also volume. all significantly influence the way these parts are designed. Accidents and their severity can be reduced with proper geometric design. As a result, A geometric design's purpose is to give the highest quality traffic operating maximum effectiveness and safety at an affordable price. In this situation, planning cannot be done in stages like it would for a pavement; rather, it must be done well in advance.

B. Factors affecting geometric design

1. Design speed

The geometric design is most significantly impacted by design speed. The sight distance, horizontal curve, and vertical curve length are all directly impacted. A design speed is used for all geometric designs because the speed of vehicles varies depending on the driver, the terrain, etc. The fastest continuous speed that a single vehicle may go on a highway safely in good weather is referred to as design speed. The legal speed limit, which is enforced to prevent drivers from exceeding an established safe speed, is distinct from design speed. The desired speed, which is the top speed at which a motorist would go in the absence of traffic and local geometry, is distinct from design speed as well. Design velocity need to be chosen so that it satisfies virtually all drivers due to the large variances in speed utilized by various drivers and vehicle kinds. Higher Other geometric patterns are affected in a cascade manner by design speed, increasing costs in the process. As a result, the normative design speed is the 85th percentile. The definition of this speed is the speed that is higher than the speed at which 85% of drivers travel. This speed can reach up to 95 to 98 percentiles in some nations.

2. Topography

The topography is the next crucial element that has an impact on geometric design. For a plain landscape, building roads that meet the necessary criteria is simpler. However, the cost of building multiplies with the grade and the terrain at a certain design speed. To keep the cost and duration of construction under control, different terrains have varying geometric design criteria. Sharper curves and steeper gradients are features of this.

3. Other factors

- *Vehicle:* A vehicle's dimensions, axle weight, and operational characteristics have an impact on design elements including pavement width, curve radii, clearances, parking geometrics, etc. Highway design regulations to accommodate cars of a specific type are established using a design vehicle with standard operating qualities, weight, and size.
- *Human:* The physically, psychologically, and mentally traits pedestrians and the driver, such as reaction time, are significant human elements that affect geometric design.

- *Traffic:* Planning the route for peak traffic flow will not be financially feasible. In light of the various traffic statistics gathered, a reasonable traffic volume value is chosen as the hourly volume design. Thus, this design volume, capacity, etc., forms the basis for the geometric design.
- *Environmental:* When designing highways geometrically, care should be given to factors like air pollution, noise pollution, etc.
- *Economy*: The design should be as cost-effective as possible. It ought to line up with the money set aside for maintenance and capital expenses.
- *Other*: The region's beauty should not be compromised by the geometric design.

C. Civil 3D Software

The software programme Civil engineers utilisee AutoCAD Civil 3D. and other using experts to plan and design building construction projects, projects involving roads, and water projects including creating ports, embankments, dams, and canals, among other things. By using AutoCAD civil 3D associate design and production drawing, design modifications may be implemented much more quickly and several scenarios can be evaluated. You can finish projects more quickly, more intelligently, and with greater accuracy by making a modification in one location that changes the entire project at once. Both small- and large-scale projects can benefit from using Civil 3D, which enables the creation of 3D models of the project. 3D visualisation facilitates conceptualization and saves time and money. Additionally, it gains several advantages from using civil 3D.

D. Objectives of the project-

- To research the different geometrical elements of roads.
- To research the function of the geometric elements of roads.
- Using civil 3D software to build geometric features.
- Using the manual method, create geometric characteristics.
- To compare studies of geometric features conducted manually and utilising civil 3D software.
- Identifying safe geometric elements for a route to reduce accident rates.

LITERATURE REVIEW

A road links and form a network of new roads that must be planned, designed, and built as part of a National Highway project. Once’s a highway is ready along with developed adjacent areas, makes it very difficult to change the alignment of geometric standards in the future. A poorly aligned highway not only increases the risk of a traffic accident but also raises the expense of transportation and puts a burden on both drivers and passengers. Therefore, throughout research and planning are very crucial for a road project, bearing in mind both the current demands of the community and its future growth. Because it satisfies both human and material needs, transportation has been crucial to civilizations' growth since the beginning of time. Road and transportation are now an essential component of every person's life in the modern world. However, it is noted that over the past ten years, the number of fatalities has increased by around 50% [1]. Previously, about 1.2 million Indians have died in auto accidents, one every four minutes on average, and 5.5 million have suffered major injuries. In India, national highways make only 1.7% of the overall road network, but they are responsible for 40% of all traffic and 29% of all traffic accidents [2].

1. Road geometry and accident frequency research

Saniya Attar, Tejaswi Desai, Divya Dugani, Sagar B. Patil1, and Simran Mahabri (2019), Finding The purpose of the study of geometric aspects of roads and accident rates is to examine various geometric features of the road using a post- and pre-analysis technique. It impacts accident rate and geometric characteristics. Traffic volume is the foundation of the investigation. Speed, horizontal radius, poor visibility, extreme height, sharp gradient, and vertical gradient all contributed to fatal incidents. For the analysis technique, a combined total of 18749 cars from 8 am to 8 pm on Waghbil road were gathered. The analysis displays the vehicle count ratio for intervals of 15 minutes. This investigation's goal was manual calculation. The project's primary focus is on road and human safety, using a fundamental methodology to facilitate understanding. The fundamental strategy for this endeavour is research, analysis, and determination. In this study, the physical elements of the highway, such as the incredibly high height, horizontal alignment, horizontal alignment, visibility, gradient, and analysis, were examined at the site of Waghbil. The providing a shortcut, posting speed limits, divergence the use of road studs and signs therefore be made to promote safe motoring in order to lower the accident rate. Measures to prevent Waghbilroad: There is heavy traffic on this road. imposed speed and divergence indicators need to be available to help reduce

traffic. Road studs should be installed at curves to prevent accidents and promote safe driving.

2. Using Autocad Civil 3d, create a geometric design for a highway

A.B. Osunkunle, K. Jirgba, S.A. Raji, A. Zava, and (2017), Using stations, altitudes, and bearings or coordinates (easting and northing), of sites along the intended route, one can create the draw the alignment profile and the road alignment. are some of the tasks involved in roadway geometry design. Other tasks include computing earthwork quantities, sight distances, horizontal curve radii, and vertical curve lengths, as well as a variety of various computations and analysis to determine the optimal alignment while meeting design standards. Geometric design is incredibly laborious, time-consuming, and prone to costly mistakes when done manually. The use of computer programmes for designing roadway geometry is in vogue right now. The programmes are extremely precise and offer significant time and effort savings. Using AutoCAD Civil 3D software, this article shows a detailed geometric design of a conventional roadway. The project's goal was to show how quickly, easily, and precisely roadway geometric design may be accomplished. The process for designing roads with AutoCAD Civil 3D has been described. The identical route was also manually designed, and the outcomes were favourably compared to those of AutoCAD Civil 3D. When AutoCAD Civil 3D is used for road geometric layout, the procedure may be finished quickly, easily, and with incredible perfection. These features of AutoCAD Civil 3D minimise the main drawbacks of the manual design process, which is laborious, labor-intensive and prone to expensive mistakes.

3. A Civil 3D Study of the Geometric Design of a Road Project

Shivam Pandey, Er. Atul, and Yogesh Bajpai (2019), — India's population is expanding quickly, which suggests that traffic is also growing. Rural region development boosts its capacity for furthering the development of transportation infrastructure. The road's alignment, sight distance, cross-section, and crossings are only a few examples of the dimensions and layout that the geometric design controls. Geometric design requires a lot of time when done manually, and mistakes can be very costly. The geometry of roads is currently designed using a variety of software programmes, including Bentley MX Road, HEADS, AutoCAD Civil 3D, etc. In order to design roadway geometry using computer programmes, prevailing patterns have been adjusted. A user can benefit from this software's clarity, time and effort savings. The thorough examination of the employing Civil 3D software for the geometric design of a road project is the focus of this research.

4. A study of roadway geometry with help Civil 3D 2020.

Prof. Kalyani P. Nichat, Akash Surendra Kolamkar (2020), India's population is expanding quickly, which suggests that traffic is also growing. Rural region development boosts its capacity for furthering the development of transportation infrastructure. The road's alignment, sight distance, cross-section, and crossings are only a few examples of the dimensions and layout that the geometric design controls. The main goals are to maximise highway safety and traffic efficiency while reducing costs and environmental harm. The fundamentals of road geometry are known to those who design roads, and the next step to improving their value is understanding how to use software. Using stations, altitudes, and bearings or coordinates (easting and northing), of locations lengths of vertical curves along the proposed route, earthwork calculations amounts, and several other studies and calculations, one can create the road alignment and map the alignment profile are all part of the geometric design of roads. These calculations are all done in an effort to find the best alignment while adhering to design standards and constraints. Geometric design requires a lot of time when done manually, and mistakes can be very costly. Currently, a variety of software programmes, including with help of Bentley MX Road and AutoCAD Civil 3D design's the geometry of roads. In order to design roadway geometry using computer programmes, current patterns have been adjusted. Using AutoCAD Civil 3D software, this dissertation shows an entire geometric design for a road project. The project's main goal is to exemplify how precise geometric design may be done in a short amount of time. The process for designing roads with AutoCAD Civil 3D has been described. A user can benefit from this software's clarity, time and effort savings. Engineering software called Civil 3D is used to design, plan, and manage civil engineering projects. Experts and civil engineers typically utilise this software.

5. A Civil 3D Study of the Geometric Design of a Road Project

Vishal Gajghate, Ravina Potey, and Ashish Kale (2021), Geometric design is a key element of the current style and has a significant impact on lining up a new route. Every road alignment is built on a

solid geometric foundation. Details of the horizontal and vertical alignment, cross-sectional sections, intersection elements, and sight distance factors and important factors like design speed, terrain or topography, and traffic considerations, environmental factors, hourly volume and capacity design, and additional elements include all covered in this document. When lining up a new road, it should be quick, simple, secure, and affordable, as well as comfortable and secure for the movement. The horizontal, vertical, and cross-sectional orientation are the three main components of the highways' geometric design. which, when put together, create a three-dimensional road design. Curves, tangents, and transitions are the three geometric elements that make up horizontal alignment. A longitudinal section that includes geometric additives like crest curves, sag curves, and slopes is called vertical alignment. The selection, estimation, and subsequent application of highway geometry formulations is based on a number of design standards, including sightlines, vehicle stability, comfort of the driver, drainage, economy, and aesthetics. Many computations and measurements are used to further the design process. This paradigm has been altered by the civil 3D upgrading so that design and development are done simultaneously. Geometrical design can be exceedingly laborious, time-consuming, and vulnerable to expensive mistakes when done manually. The traditional method is also dependent, in particular, an analysis based on two dimensions that does not assure a pleasing arrangement. To help professionals from the developing world employ road design, this study aims to demonstrate how geometrical design may be completed swiftly and flawlessly. With the use of AutoCAD Civil 3D, this paper illustrates a typical roadway design while saving time and resources. Without 3D modelling, designing a highway confronts enormous difficulties. To cut and fill those amounts takes a lot of work. You can employ the volume computing strategy.

GEOMETRIC DESIGN BY MANUAL METHOD

Geometric Design: Highway geometry design include creating the actual, observable features of the road, such as cross sections, sight distances, alignment, bends, super elevation, and other related factors. These geometrical elements are briefly defined here.

Alignment: The alignment, which is represented as a jumble of horizontal curves and tangents, represents the route used by the road.

Profile: The grade lines that link the road's crest and sag curves are part of the road's profile, which is its vertical aspect.

Cross-section: The cross section displays the location, number, and cross slope or banking of the bike, automobile, and pedestrian lanes and walkways. Cross sections also reveal the pavement's structure, drainage systems, and other non-geometric elements.

Sight distance: Road geometry has an impact on the driver's possible sight distance. The length of the roadway that the driver can see in front of them is referred to as sight distance in the context of road planning.

Cross slope: A roadway's slope that is perpendicular to the centerline is referred to as cross slope. A flat road would allow water to run off of it.

Crest curves: Curves that are convex upward when viewed from the side are known as crest vertical curves. This includes the vertical bends at the tops of hills, as well as places when an uphill slope lessens or a downhill grade increases.

Superelevation: The outside edge of the pavement is elevated in comparison to the inner edge in order to counteract the effects of centrifugal force and reduce the possibility that cars would flip over and skid outward laterally. Super elevation is the process of providing a transverse slope.

Curves that are horizontal: Curves that are horizontal are available to alter the direction of the road's centerline. rotational motion, which based on the radius and speed of the curve of vehicle, acts outward through the vehicle's centre of gravity when it negotiates a horizontal curve.

Transition curve: A transition curve is a new concept whose radius falls off of infinity at the Pointing a tangent to a predetermined the circumference of the circle to enable the progressive introduction of superelevation Considering the impact of a vehicle's centrifugal force navigating a horizontal curve.

Horizontal Curve Radius: One crucial part of the geometric design is the horizontal curve's radius. The radius of a horizontal curve determines the highest tolerable speed. Even while it is technically possible to build the curve with the highest friction coefficient and superelevation,

doing so is not recommended because it would necessitate re-alignment should the design speed increase in the future. As a result, By assuming the highest superelevation and friction, a ruling minimum radius R_{ruling} can be determined.

$$R_{ruling} = \frac{v^2}{g(e+f)} \quad (1)$$

The curve's radius should ideally be greater than Rruling. Large curves, however, are also not preferred. It becomes challenging to lay out huge curves in the field. Additionally, it makes driving more difficult.

Design of super-elevation:

It is safe to provide higher superelevation for swiftly moving automobiles without taking frictional coefficient into account since the a rotating force is completely offset by the vehicle's weight or the superelevation. Since a rotating force is countered by friction coefficient and superelevationss, giving lower superelevation for slowly moving vehicles is safe.

IRC advises using the following design process:

1. Neglecting f, find e at 75% of design speed.

i.e $e_1 = \frac{(0.75v)^2}{gR}$

2. If, $e_1 \leq 0.07$ then $e = e_1 = \frac{(0.75v)^2}{gR}$ else if $e_1 > 0.07$ go to step 3.

3. f_1 for the design speed and e_{max} should be found.

i.e $f_1 = \frac{v^2}{gR-e} = \frac{v^2}{gR-0.07}$

If $f_1 < 0.15$, then the $e_{max} = 0.07$ is safe for the design speed, else go to step 4.

Find the maximum speed va given the greatest values of *e* and *f*.

$$va = \sqrt{0.22gR}$$

If *va*>*v*, the design is sufficient; otherwise, apply speed control measures or look for speed control measures.

Extra widening (W_{ep}):

widening more than usual for psychological reasons. (W_{ep})

The driver tends to follow the inside of the pavement when negotiating a horizontal curve. As a result, the During bends, the effective pavement width is reduced. You should provide an extra widening at the bend of the road in order to have a efficient operation there.

due to psychological factors, the IRC proposed a value of additional widening formula.

$$W_{ep} = \frac{v}{9.5\sqrt{R}}$$

Mechanical Widening (W_{em})

The inner track is more likely to be followed by the rear wheels while negotiating a curve. There will be a mechanical widening that must be constructed in order to accommodate this. The vehicle's off-tracking is to blame for this.

One of the key considerations while designing curve widening is the off-tracking in a roadway.

Given by is the IRC value for the mechanical widening.

$$W_{em} = \frac{nl^2}{2R}$$

Therefore;

Total extra widening formula is = $W_{ep} + W_{em}$

$$W_{ep} = \frac{v}{9.5\sqrt{R}} + \frac{nl^2}{2R}$$

Where;

n=Number of lanes
l=Length of the curve
R=Radius of curve or curvature

Stopping Sight Distance (SSD):

$$SSD = vt + (\frac{1}{2gf})v^2$$

Here, v stands for velocity in metres per second, t for reaction time, f for coefficient of friction, and g for gravitational acceleration.

$$SSD = \left(\frac{v^2}{2g(f \pm 0.01n)}\right) + vt$$

Here, v denotes speed in metres per second, t denotes response time, f denotes coefficient of friction, g denotes gravitational acceleration, and n denotes gradient.

5. ISD: Intermediate Sight Distance

It is the sight distance necessary to regularly allow overtaking on motorways. Its value equates to twice that of S.S.D. (stopping sight distance)

ISD therefore equals 2 times SSD.

$$ISD = 2(vt + \frac{v^2}{2gf})$$

THE AUTOCAD CIVIL 3D DESIGN PROCESS

- Import survey data into the AutoCAD Civil 3D environment, including easting, northing, and levels data saved in Note Pad format.
- Improve the ground surface
- Use polylines to align objects by connecting points on the ground as it is now.
- Use the design standards. The AASHTO design guidelines were chosen for this project.
- Produce the current ground profile.
- Utilize the profile generation tools to create the formation level (completed).
- Produce the Assembly, which outlines the design's cross-sectional element. Individual

subassembly objects are connected to form the assembly.
- Construct the corridor, a dynamic 3D model that is the result of combining cross-sectional, horizontal, and vertical design elements. Corridors can be used to generate surfaces, Perform sight and visual analysis, compute earthworks and quantity takeoffs, and extract data for construction.
- Produce a report on a volume table.

CONCLUSION

Highways are supposed to guarantee the comfort and safety of users, to enable effective traffic flow, and to command the least expensive construction and maintenance costs. Highways are also anticipated to harm the environment as little as possible and to be aesthetically beautiful when completed. These requirements are satisfied by geometric design. Geometric design "focuses on the specific measures that provide for efficient and appropriate operation of the road, as well as provide for all the specific details that make roads safe and compatible with social and environmental circumstances surrounding the road," according to the American Association of State Highway and Transportation Officials (AASHTO).

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